Last Name: ________________ First Name: _____________ Thermo no. _____

ME 200 Thermodynamics 1
Fall 2017 – Final Exam

Circle your instructor's last name	
Division 1: Naik	**Division 2: Sojka**
Division 3: Wassgren	**Division 4: Goldenstein**
Division 6: Braun	**Division 7: Buckius**
Division 8: Meyer	

Number of extra pages used if any

INSTRUCTIONS

- **Do not remove staplers from any page**. If you use extra paper, attach it at the end of the exam with a paper clip and indicate below how many sheets were used.
- **Do not write on the back of any page because it will not be scanned so will not be graded**
- **This is a closed book and closed notes exam. Equation sheets and all needed tables are provided.**
- Significant credit for each problem is given if you identify your system and its boundary, draw the relevant energy flows on a diagram i.e. Energy Flow Diagram (EFD), start your analysis with the basic equations, list all relevant assumptions, and have appropriate units and use three significant figures. There is no need to re-write the given and find.
- Do not hesitate to ask if you do not comprehend a problem statement. For your own benefit, please write clearly and legibly. **You must show your work to receive credit for your answers.**

IMPORTANT NOTE

The use of PDAs, Blackberry-type devices, cell phones, laptop computers, smart watches or any other sources of communication (wireless or otherwise) is strictly prohibited during examinations. Doing so is cheating. If you bring a smart watch, cell phone, or other communication device to the examination, **it must be turned off** prior to the start of the exam, **placed in your backpack, and the backpack must be stored below your seat**. It shall be **reactivated only after you leave the examination room for the final time**. Otherwise it is a form of cheating and will be treated as such.

SECOND IMPORTANT NOTE

The only calculators allowed for use on this exam are those of the TI-30X series. No others.

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1. [25 points] Circle the **one** correct answer for each (no partial credit; no justification required).

(a) (2 points) An ideal gas is contained in a closed, frictionless piston-cylinder device. The gas is heated at constant pressure using heat transfer from a hot reservoir. During the process, the density of the gas:

Increases Decreases Remains Same

(b) (2 points) An ideal gas is contained in a closed rigid tank. The gas is heated using heat transfer from a hot reservoir. During the process, the density of the gas:

Increases Decreases Remains Same

(c) (3 points) For an ideal gas with constant specific heats, the change in internal energy is $\Delta u = C_v \Delta T$ for which of the following processes?

Constant volume process Constant pressure process
Constant entropy process All of the above

(d) (4 points) For an ideal gas, the specific heat at constant volume is 1 kJ/kg-K and the molecular weight is 8.314 kg/kmol. Which of the following is the specific heat at constant pressure for this gas?

1 kJ/kg-K 2 kJ/kg-K
7.314 kJ/kg-K 9.314 kJ/kg-K

(e) (4 points) Superheated water vapor at 100 bar and 320°C (h = 2790 kJ/kg) is throttled to 20 bar in an adiabatic, no work expansion valve. Which of the following is the temperature at the exit of the throttling valve?
At 20 bar: T_{sat} = 212°C, h_f = 910 kJ/kg, h_g = 2800 kJ/kg

64°C 212°C
320°C Insufficient Information

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Problem 1 (continued)

(f) (2 points) A well-insulated rigid tank having no external work interaction is divided into two equal volumes by an internal partition. Each side contains an equal mass of gas with the same temperature, but at different pressures. The partition is removed and the gases mix until equilibrium is reached. Which of the following statements is true?

Total internal energy of the two gases increases

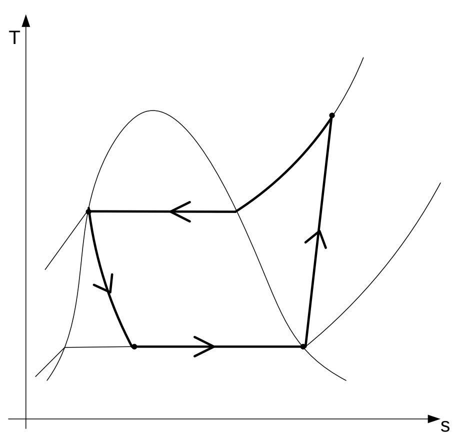
Total internal energy of the two gases decreases

Total entropy of the two gases increases

Total entropy of the two gases decreases

System operates as a cycle and all the properties remain unchanged

(g) (2 points) The cycle shown on the T-s diagram below could be a:



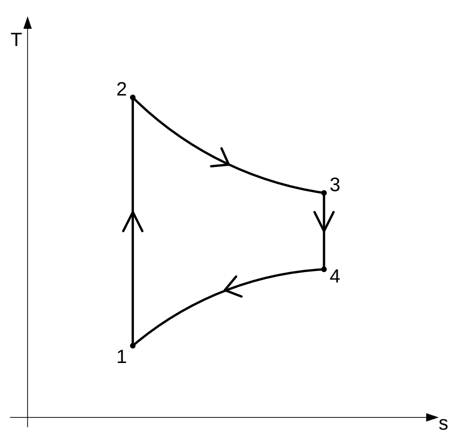
Rankine cycle

Refrigeration cycle

Brayton cycle

Insufficient information

(h) (2 points) A cycle consists of internally reversible processes as shown below. Which of the following is true?



There is net heat transfer to the working fluid

There is net heat transfer from the working fluid

Process 2-3 is adiabatic

Process 4-1 has heat transfer to the working fluid

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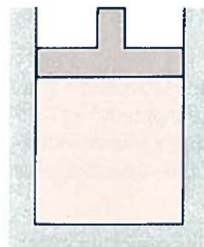
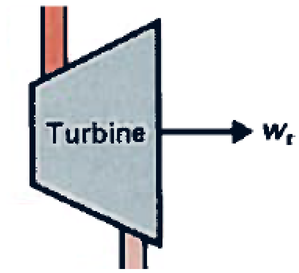
Problem 1 (continued)

(i) Given the two systems shown below (a closed piston-cylinder device and a turbine with mass flow), <u>for each blank indicate yes or no</u> if the system can have contributions of Pdv work or vdP work.





Pdv work	_________(1 point)	________(1 point)
vdP work	_________(1 point)	________(1 point)

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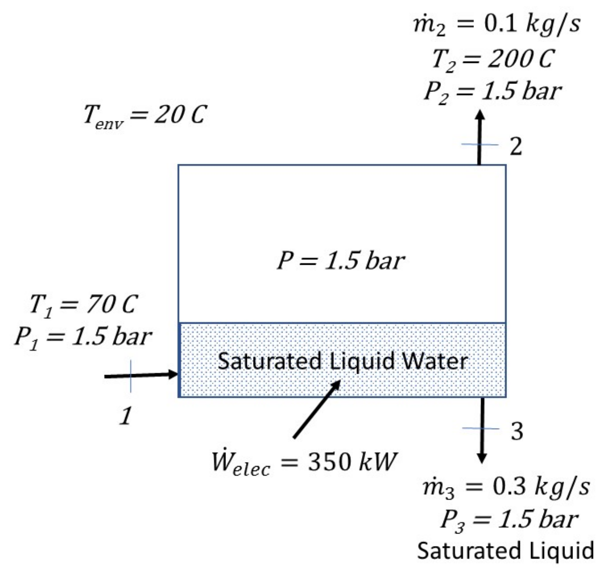
2. [25 points] An electrically heated system is used for an industrial application where both vapor and liquid streams are needed for different processes. The system operates at steady state and consumes electricity at the rate of 350 kW. Liquid water enters at 1.5 bar and 70°C (State 1), while 0.1 kg/s of superheated water vapor exits at 1.5 bar and 200°C (State 2) and 0.3 kg/s of saturated liquid water exits at 1.5 bar (State 3). The outside surface of the system has heat transfer to its local environment whose temperature is 20°C. The given pressure is absolute.



(a) Complete the properties in the table at each of the state points.

State	P (bar)	T (°C)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg-K)
1	1.5	70			
2	1.5	200			
3	1.5				

(b) Determine the rate and direction of heat transfer (kW) between the system and the environment.
(c) Calculate the total rate of entropy generation (kW/K).
(d) If an external heat transfer of 350 kW from a source at 1000°C were to be used instead of electrical heating power of 350 kW, then comment on whether the total rate of entropy generation would increase, decrease, or remain the same. Justify your answer with a basic equation.

Identify appropriate system or systems on the sketch provided, show mass/energy interactions (EFD), list any assumptions and basic equations, and provide your solution. There is no need to re-write given and find.

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Extra Space for Problem 2

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Extra Space for Problem 2

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3. [25 points] Air contained in a piston-cylinder device undergoes a cycle comprised of the following four internally reversible processes.

Process 1 to 2: Constant temperature ($T_2 = T_1$) from P_1 = 1 bar and T_1 = 300 K to P_2 = 10 bar during which heat transfer occurs from the air
Process 2 to 3: Constant pressure ($P_2 = P_3$) to T_3 = 1500 K during which heat transfer occurs to the air
Process 3 to 4: Constant temperature ($T_3 = T_4$) during which heat transfer occurs to the air
Process 4 to 1: Constant pressure ($P_4 = P_1$) during which heat transfer occurs from the air

The heat transfer from the air during the process from state 4 to 1 is used for the heat transfer to air during the process from 2 to 3. The two heat transfers are equal in magnitude and are internal to the system i.e. they do not interact with the external environment.

(a) Show the cycle on P-v and T-s diagrams with relevant lines of constant pressure and temperature. Label the axes and four states and indicate the process directions with arrows.
(b) Calculate the specific heat transfer (kJ/kg) for process from state 1 to 2 and for process from state 3 to 4.
(c) Determine the thermal efficiency (%) of the cycle.

Identify the system, show mass/energy interactions (EFD), list any assumptions and basic equations, and provide your solution. There is no need to re-write the given and find.

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Extra Space for Problem 3

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Extra Space for Problem 3

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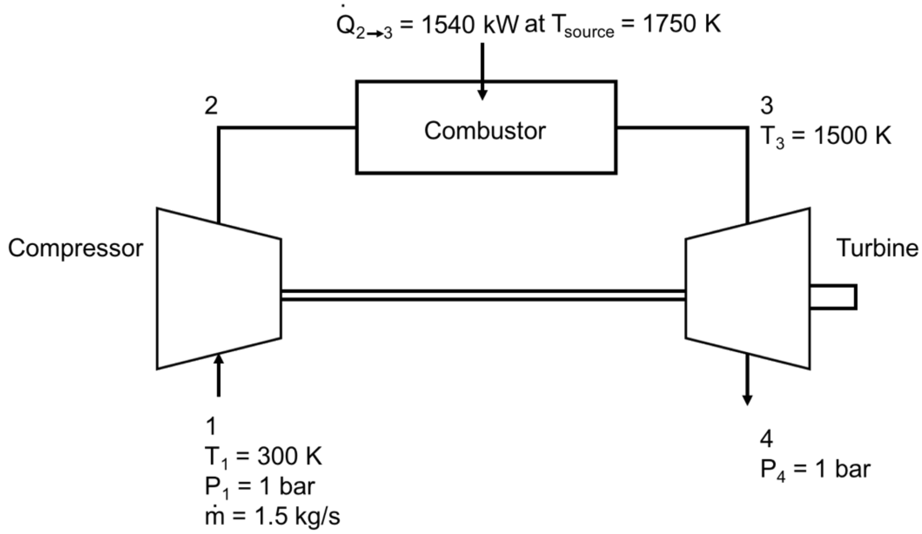
4. [25 points] The Brayton cycle shown in the schematic below is used to generate electricity. Air enters the isentropic compressor at $T_1 = 300$ K and $P_1 = 1$ bar (absolute) (State 1) with a mass flow rate of 1.5 kg/s. The combustor can be modeled as a constant-pressure heat exchanger ($P_2 = P_3$) which supplies 1540 kW of thermal power to the air. Air enters the turbine at $T_3 = 1500$ K (State 3) and exits at $P_4 = 1$ bar (absolute) (State 4). The turbine is internally reversible, but not adiabatic and the expansion through the turbine is polytropic with $Pv^{1.3}$ = constant.



Use the closest value in ideal gas table; do not interpolate.

(a) What is the temperature T_2 (K) at the compressor exit?
(b) Calculate the pressure ratio (P_2/P_1) across the compressor.
(c) Determine the rate of entropy generation (kW/K) for the combustor if heat transfer occurs at a boundary temperature of 1750 K.
(d) Find the power (kW) produced by the turbine.

Identify appropriate system or systems on the sketch provided, show mass/energy interactions (EFD), list any assumptions and basic equations, and provide your solution. There is no need to re-write the given and find.

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Extra Space for Problem 4

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